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# WATERTOWN ARSENAL LABORATORIES

THE ROLE OF DILUTE BINARY TRANSITION ELEMENTS  
ON THE RECRYSTALLIZATION OF TITANIUM

TECHNICAL REPORT NO. WAL TR 830.3/6

BY

ERNEST P. ABRAHAMSON, II

DATE OF ISSUE - NOVEMBER 1961



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D/A PROJECT 5893-32-001

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Recrystallization  
Transition elements  
Titanium

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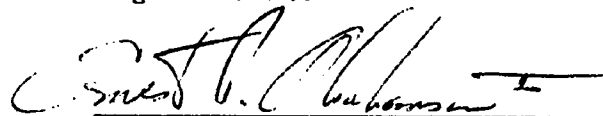
WATERTOWN ARSENAL LABORATORIES

TITLE

THE ROLE OF DILUTE BINARY TRANSITION ELEMENTS  
ON THE RECRYSTALLIZATION OF TITANIUM


ABSTRACT

The effect of transition element binary solid solution additions upon the recrystallization temperature of titanium has been investigated. All additions, except columbium and tungsten, raised the recrystallization temperature. A correlation is obtained between the logarithm of the absolute rate of change of recrystallization temperature with atomic percent solute and the number of outer d shell electrons attributed to the free atom of the solute element in its ground state.



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J. F. SULLIVAN  
Director  
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## INTRODUCTION

The work of Abrahamson, et al,<sup>1-6</sup> on dilute binary solid solution alloys indicated a correlation between the free atom ground state electron configuration of the solute and both the brittle-ductile transition and recrystallization temperature. It is shown in these studies that the number of outer s and d electrons in the solute are of prime importance in determining the absolute rate of change of recrystallization or transition temperature with composition. Furthermore, the limit of initial linearity (in the curve of recrystallization temperature versus atomic percent solute) has been shown to be a function of the number of d shell electrons in the solute for dilute iron and vanadium base alloys.

To date no complete systematic recrystallization study of dilute binary titanium base alloys has been made.

This study together with that of zirconium base alloys<sup>6</sup> will provide the data for the comparison of the effect of the same solutes upon two solvents with the same number of outer d shell electrons.

## PROCEDURE

All alloys were made using 99.9+% iodide Ti with 0.005 Si, 0.001 Al, 0.001 Mg, 0.005 Mn, 0.004 Mo, 0.0005 Fe, 0.02 C, 0.005 N and 0.026 O (60 Rockwell F). The solute elements were 99.9+% pure. According to the published binary phase diagrams<sup>7,8</sup> and metallographic examinations at 750X, all alloys used were in solid solution.

The alloys were arc melted and remelted six times in the form of cubic 200-gram buttons under an argon atmosphere. They were then hot pressed at 950 C to 0.450 inch, upset pressed to 0.350 inch and annealed at 1000 C for 45 minutes. The specimens were then Blanchard ground to 0.250 inch, removing 0.050 inch from each side. The grain size of the material at this stage was found to be  $80 \pm 10$  grains per square millimeter. The specimens were then cold rolled to 0.130 inch and cold pressed to 0.125 inch, yielding  $50 \pm 1\%$  cold work. All alloys were then analyzed chemically for the principal addition. When checked, the interstitial contents of random alloy specimens remained at the values of the starting material.

The rolled sheet was cut into 6.75 x 0.25-inch lengths and heat treated in a gradient furnace for one hour. The gradient was 275 to 850 C over the six-inch length, recorded continuously by six thermocouples resting on each specimen. Control was  $\pm 3$  C, accomplished at the hot end.

The recrystallization temperature was determined metallographically using polarized light. The criterion chosen was the point on the specimen showing the first recrystallized grain at a constant magnification, 200X. Duplicate specimens were tested and the agreement was found to be  $\pm 3$  C.

## RESULTS

Five different pure titanium specimens were tested, and the recrystallization temperature was found to be  $490 \pm 3$  C. Figures 1 through 3 show the effect of the transition elements on the recrystallization of titanium. Columbium and tungsten lowered the recrystallization temperature, while the other elements raised the recrystallization temperature.

If one considers the absolute slopes of the curves in Figures 1 through 3, a definite periodicity can be noted. Figure 4 demonstrates this periodicity when the logarithm of this parameter is plotted versus the free atom ground state electron configuration<sup>9</sup> of the solutes. The elements shown as dotted points are based on less than the desired amount of data to sufficiently determine the slope. However, these points are used to indicate the general shape of the curves.

## DISCUSSION

As with previous recrystallization as well as brittle-ductile transition studies,<sup>1-6</sup> the absolute change in recrystallization temperature does correlate with the number of outer d shell electrons in the solute for titanium base alloys. The curves presented in Figure 4 in the form of inverse V's exhibit an apex at tantalum,  $4d^35s^2$ . This is in agreement with prior observations<sup>5,6</sup> that the apex occurs for the  $s = 2$  curve at those elements having one more d shell electron than the solvent,  $Ti-3d^24s^2$ .

Comparing Figure 4 with similar correlation curves for zirconium,<sup>6</sup> it is observed that the results are almost identical. Both zirconium and titanium have the same number of outer d shell electrons. Thus it is evident that not only do solutes with like configurations behave similarly in the same solvent, but also solutes behave similarly in solvents with the same electron configuration.

It will be noted that two elements lowered the recrystallization temperature of titanium, while all elements raised the recrystallization temperature of zirconium.<sup>6</sup>

Prior work<sup>3,4</sup> has shown that the breaks from linearity observed in Figures 1 through 3 are also functions of the number of solute d shell electrons. The data in this study, however, are insufficient to establish any such correlation.

## CONCLUSIONS

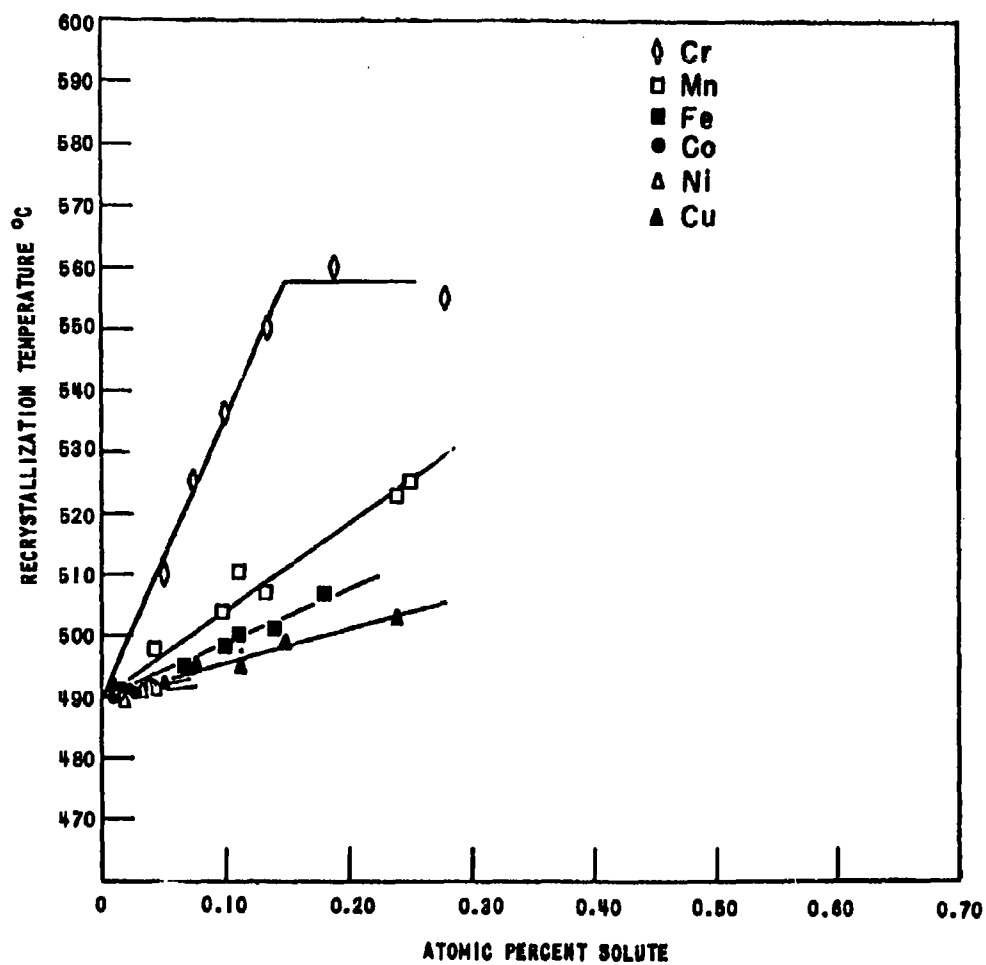
1. A correlation is noted between the absolute value of the slope of the recrystallization temperature versus atomic percent solute curve and the number of outer d shell electrons attributed to the solute atom in the ground state. The curve is in the form of an inverse V with an apex at tantalum on the  $s = 2$  electrons curve.

2. Columbium and tungsten lower the recrystallization temperature of titanium while the other transition elements raise it.

3. Solvent elements having a like number of outer d shell electrons accomplish a like absolute change in recrystallization temperature when alloyed with the same solute elements.

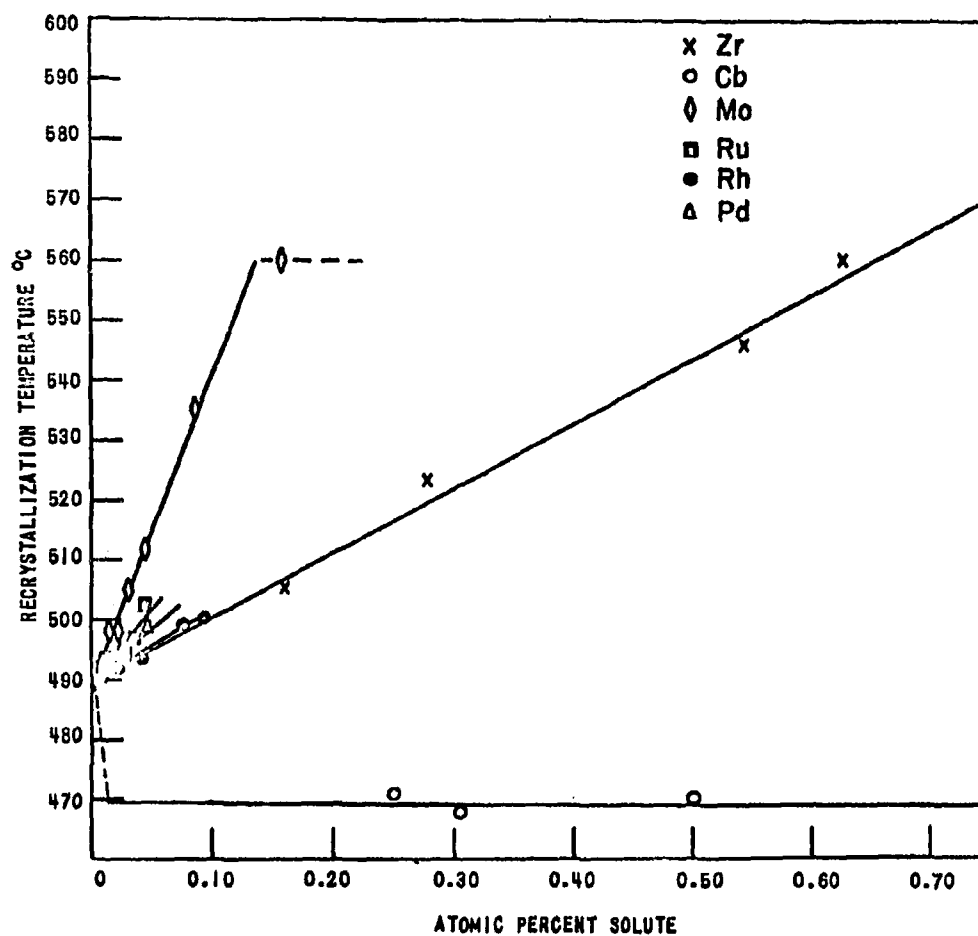
#### ACKNOWLEDGMENT

Grateful acknowledgment is made for the assistance given by J. A. Alexander, J. M. Dhosi, and Dr. F. Rhines through their many helpful discussions.

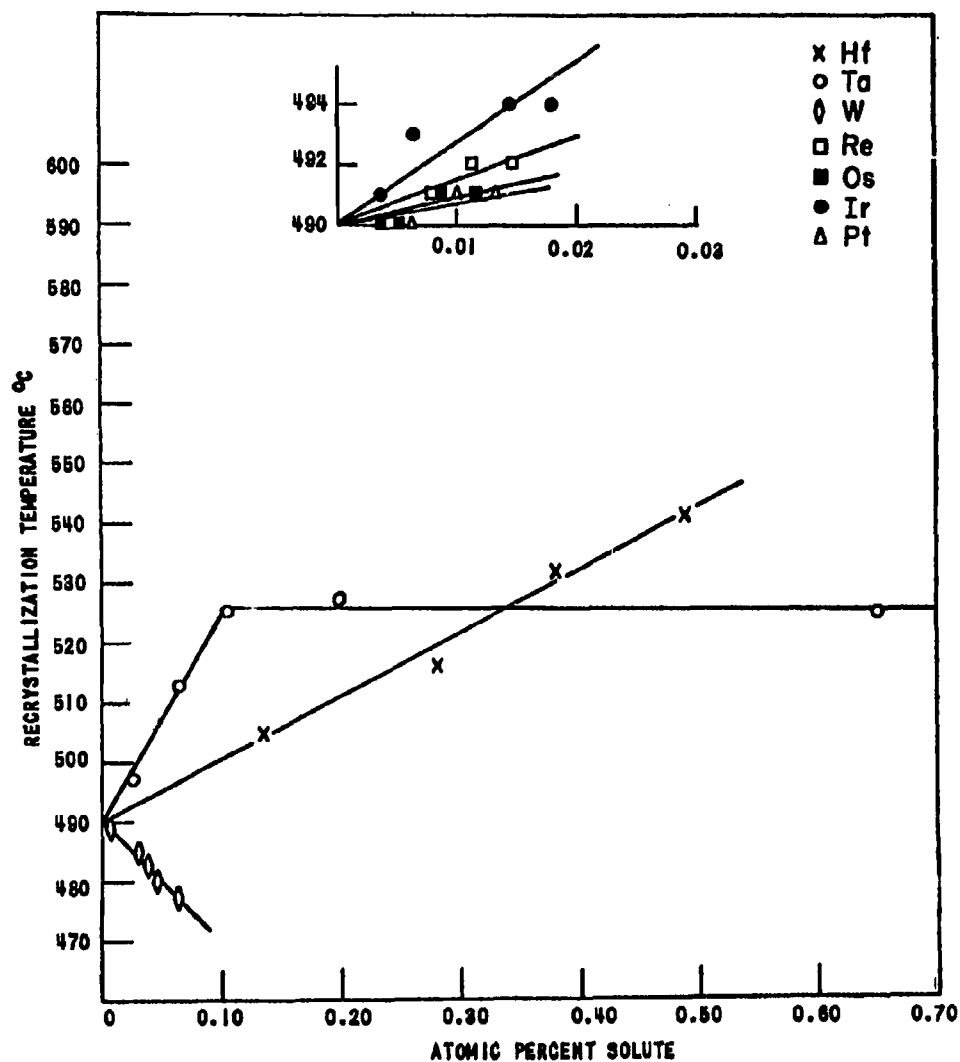


RECRYSTALLIZATION TEMPERATURE OF TITANIUM AS A FUNCTION OF THE ATOMIC PERCENT BINARY SOLUTE ADDITION FROM THE FIRST TRANSITION SERIES

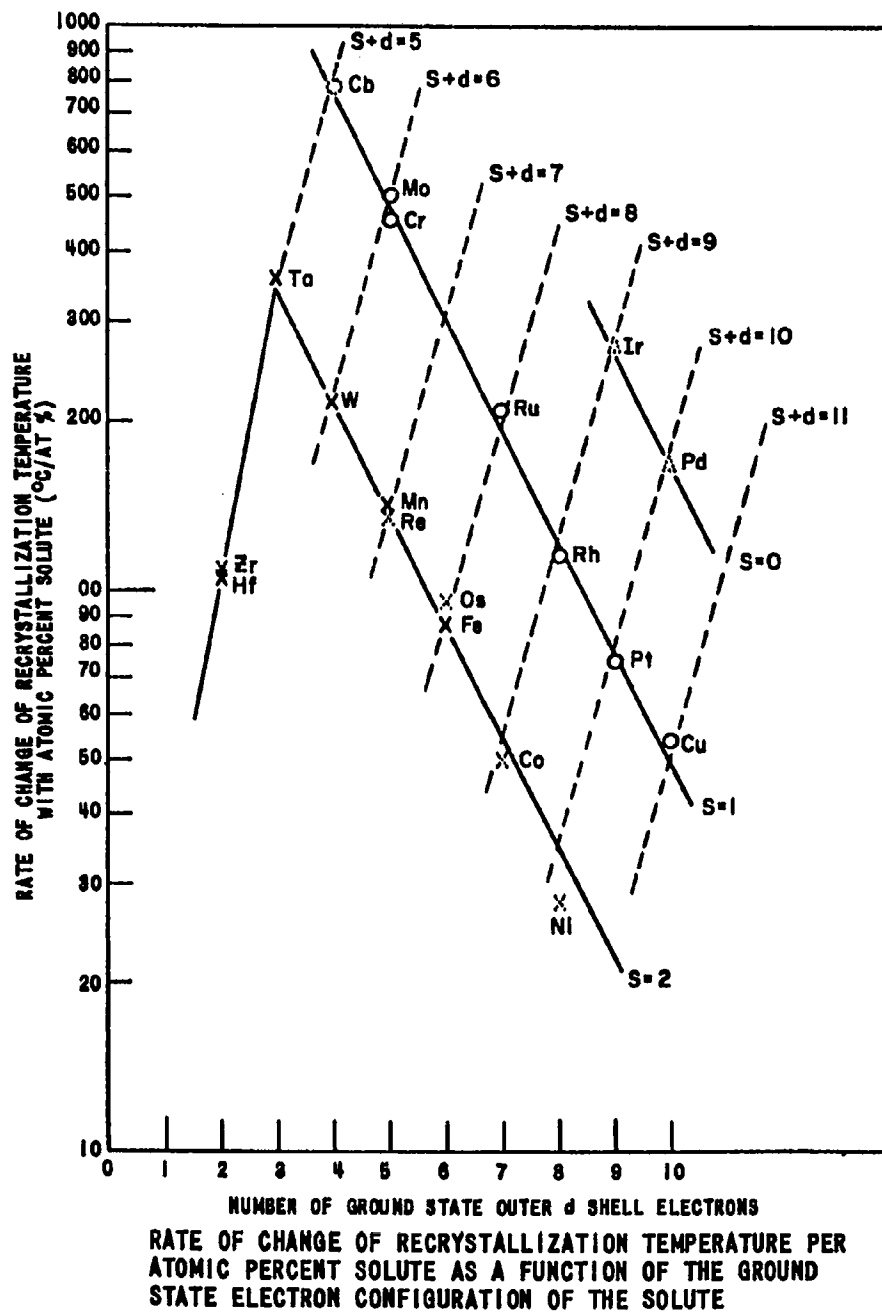




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